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The current status of Russian/CIS communication satellites

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THESIS

THE CURRENT STATUS OF RUSSIAN/CIS
COMMUNICATION
SATELLITES

by

Larry E. Ninas

September, 1994

Thesis Advisor: Randy Wight

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13. ABSTRACT

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This thesis presents a brief history of the Soviet/Russian communication satellite program, and an examination of current systems as well as future and "on-order" sytems. Simulations were conducted to determine the useability of the major systems (Gorizont, Ekran, Molniya, and Raduga) from 17 geographic locations. This is concluded with an introduction to the Telemedicine Spacebridge Project that is a direct result of the Bush-Gorbachev summit, and a shining example of Russian/U.S cooperation in the satellite communication arena.

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THE CURRENT STATUS OF RUSSIAN/CIS COMMUNICATION SATELLITES

by

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of the requirements for the degree of

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ABSTRACT

As part of a Memorandum of Understanding (MOU) signed by U.S. President George Bush and Soviet President Mikhail Gorbachev during a July 1991 summit meeting, the U.S. agreed to expand civil space cooperation with the Russian Federation and the Commonwealth of Independent States (CIS). The goal of this MOU was "to increase the technical capabilities of both sides to respond to both natural and man-made disasters" and "to benefit from the capabilities and involvement of international and non-government organizations." This summit agreement has allowed the Russian Federation to offer unprecedented commercial and emergency relief access to their on-orbit communication satellites.

This thesis presents a brief history of the Soviet/Russian communication satellite program, and an examination of current systems as well as future and "on-order" systems. Simulations were conducted to determine the usability of the major systems (Gorizont, Ekran, Molniya and Raduga) from 16 geographic locations. This thesis concludes with an introduction to the Telemedicine Spacebridge Project that is a direct result of the Bush-Gorbachev summit, and a shining example of Russian/U.S. cooperation in the satellite communication arena.

TABLE OF CONTENTS

I. INTRODUCTION

A. OVERVIEW

President Mikhail Gorbachev and President George Bush signed a Memorandum of Understanding (MOU) on disaster assistance during a summit held on July 30-31, 1991. A significant part of this MOU dealt with civil space programs in relation to disaster assistance. It was hoped that this MOU would led to an increased technical capability of both parties to respond to manmade (Chernobyl) and natural disasters (the 1989 Azerbaijan earthquake). (Zuzek, 1994, p. 1)

This thesis will give an overview of major Russian/Commonwealth of Independent States (CIS) communications satellites and their capabilities. Additionally, analysis of the major constellations (Gorizont, Raduga, Molniya, and Ekran) will be conducted against sixteen geographic locations around the globe to assess the usability of each satellite in each system at that location. Locations within the continental U.S. were not used, based on the assumption that relay satellites would be used to route the communications. The analysis will be conducted using TRAKSAT, a general purpose satellite tracking program using NORAD, NASA two-line element sets. The

solution to the satellite motion which is used by TRAKSAT is completely analytic and therefore requires no numerical integration. Satellites were simulated for a period of 30 days, checking for satellite availability at midnight and noon Greenwich Mean Time (GMT). This procedure yielded a maximum possible total per satellite of 60. The results are reported as a percentage of 60. Analysis for each system is provided in the chapter relating to that system.

This thesis is not meant to be a comprehensive examination of Russian/CIS communications satellites. The information contained herein is perishable, since the systems examined are constantly being improved and updated. Since the primary emphasis is on geosynchronous satellites and highly elliptical satellites, near-circular low-earth orbit satellites will be discussed only briefly in the first chapter.

B. AN ABBREVIATED HISTORY OF RUSSIAN SATELLITE COMMUNICATIONS

The Soviet Union fired the first salvo in the "space race" that dominated the 1960's and 1970's with the launch of Sputnik on October 4, 1957. What followed was a flurry of artificial satellite launches with the U.S. launching Explorer I and the Soviets launching Molniya 2 in November 1957 and Molniya 3 in May of 1958. While the U.S. has led the world in satellite communications technology, the Commonwealth of Independent States (as the former Soviet Union is now known) is still the leader in number of annual launches, as Figure 1 illustrates graphically.

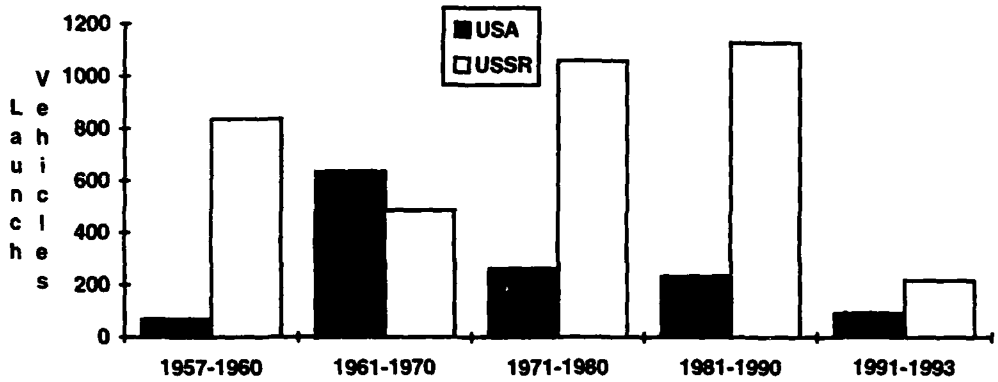

Figure 1. Comparison of U.S. and USSR Space Vehicle Launches (Kelso, 1994)

The Soviet Union at the time of Molniya covered 8,650,010 square miles .(Rand McNally, 1983, p. 286) With a country this large, spanning eleven time zones, it was imperative that the Soviets turn to long haul communications satel-

lites early on to build a telecommunications and broadcast infrastructure. Much of that infrastructure is still in use today.

Soviet/CIS communications satellite orbits fall into three categories: highly elliptical, low altitude near-circular, and near geostationary. The first of the highly elliptical orbit satellite systems was launched on April 23, 1965 and identified as Molniya 1-01 (NORAD 1965 030A). Known as the "Molniya orbit", it has an orbital period of approximately 12 hours and an inclination of 63^{o}-65^{o}. Because of this inclination, the apogee of the satellite remains over the northern hemisphere, providing full coverage of the CIS and portions of the Arctic Circle. This system allowed the exchange of television programs between cities as far apart as Vladivostok and Moscow. Molniya 1-01 decayed from orbit on August 16, 1979. However, this system is still maintained with regular launches.

Two low altitude constellations make up what is considered the lowest tier of the Russian Federation's command, control and communications (C^3) system. Cosmos 332 (NORAD 1970-028A) was the first satellite in the initial constellation. Launched on April 11, 1970, it was the first of the Soviet low altitude near-circular satellites, with an apogee of 735 km and a perigee of 728 km. The second constellation in this lowest tier was established with

the launch of Cosmos 336 (1970-036A) on April 25, 1970 but with an altitude twice that of the first system (apogee 1484 km, perigee 1461 km).[Satellite Data, 1994]

These two constellations share a common inclination of 74°, and they are easily distinguished by their launch patterns. That is, the first system is usually launched as a "singleton", and the second in groups of eight (or octets). Each of these systems was advertised to be used primarily for government and military use. A third system, known as Gonets, is a sextet system that was offered commercially in 1990, and features store and forward communications. A military constellation of the Gonets system was established in 1985.

Near-geostationary systems lagged the launch of the U.S. geosynchronous operation (SYNCOM satellite) by ten years, but the Soviets quickly made up for lost time starting in the mid-1970's. The first of the Raduga series (reserved for government and military communications) was launched in December 1978, with the 29th arriving on orbit in the fall of 1993. The Soviets first direct broadcast UHF TV service began with the first in a series of Ekran satellites being launched on October 26, 1976. The Ekran series is undergoing its second phase with the introduction of the first dual frequency satellite, Ekran-M, in 1987.[Commercial, 1993, p. 53] With the success of inflight tests,

launches to replace the aging Ekran system with Ekran-M satellites should begin in the near term.

The Gorizont system began its service with the first space vehicle on orbit in December 1978. The Gorizont satellites provide not only domestic television and telephony, but also international television and telephony services via InterSputnik.

The final system to be discussed, Luch, began life as a transponder aboard Gorizont 5 in 1982. The purpose of the Luch system is to provide a satellite data relay network (SDRN) to communicate with manned space stations and other spacecraft operating in low earth orbit.

Despite this array of communications satellites, the capacity for communications within Russia and the CIS are limited. In 1988, only 23 percent of urban families and 7 percent of rural families had telephones. (Johnson, 1988, p. 22) The International Telecommunications Union (ITU) indicates that approximately 36,000 rural settlements in the Russian Federation are without telephone service. Although it would seem logical and cost effective to convert the largely military satellite industry to commercial purposes, it has not proven easy. Despite the difficulty, the Russian/CIS satellite industry has turned to commercialization of their efforts to stay afloat.

II. THE MOLNIYA SYSTEM

A. BACKGROUND AND DEVELOPMENT

The most well-known of the Russian communications satellite systems is the Molniya system. The inauguration of the unique Molniya orbit and the system began with the placement of Cosmos 41 into a 64° inclination orbit on August 22, 1964. Cosmos 41 (NORAD 1964-049D) was the first highly elliptic orbit satellite with perigee in the Southern Hemisphere of only 400 kilometers and apogee over the Northern Hemisphere at 40,000 kilometers. This unique orbit allowed Cosmos 41 an unprecedented field of view (FOV) that included the North Pole, most of the Northern Hemisphere and at that time the entire Soviet Union.[(Johnson, 1988, p. 22)] This lingering effect over the Soviet Union due to a slower velocity at apogee, indicated that a constellation of only three satellites in this highly elliptical orbit could provide continuous 24-hour coverage. Molniya 1-1 was launched on April 23, 1965, and provided the first spaceborne Moscow-to-Vladivostok television transmissions.

The Molniya constellation utilizes the Orbita ground network, which became operational in 1965. The Orbita system is capable of providing 480 duplex channels. The Molniya system proved effective in deterring the nor-

mal orbital effects of near-circlar, low-earth orbit (LEO) launches from Tyuratam and Plesetsk Cosmodromes. What was more obvious was the monetary savings of this system. Construction of the first 60 ground stations took seven years and cost approximately 100 million rubles. A comparable terrestrial network constructed at the same time is estimated to have cost several billion rubles, and took several decades to complete.(Johnson, 1987, p. 59)

Two constellations of three satellites each normally comprise the Molniya constellation. Initially, the satellites were separated by 120°, guaranteeing at least eight hours per day of access to each satellite. In 1969, with the launch of Molniya 1-11, the spacing was reduced to 90°, thereby increasing the number of Molniya above the horizon at any one time to three vice two.(Wilson, 1992, p. 410)

B. MOLNIYA 1

Molniya 1 satellites (Figure 2-1), in use since 1965, are three-axis stabilized with gimbaled antennae and sun-seeking optical sensors. Redundancy was the foundation of the Molniya 1 system. The spacecraft are equipped with two antennas (18 dB antenna gain), with only one operational at any one time in order to extend operational life. Additionally, there are a total of three transceivers onboard, with one active and the other two in standby,

also to extend operational life. Equipment is and was solid state "except for metal ceramic triodes, klystrons (an electron tube for the generation and amplification of ultrahigh frequency current), magnetrons and traveling wave tubes (amplifiers)."(Van Horn, 1987, p. 78) There were and are usually three active and one spare traveling wave tubes, each with a lifetime of approximately 40-50 thousand hours.

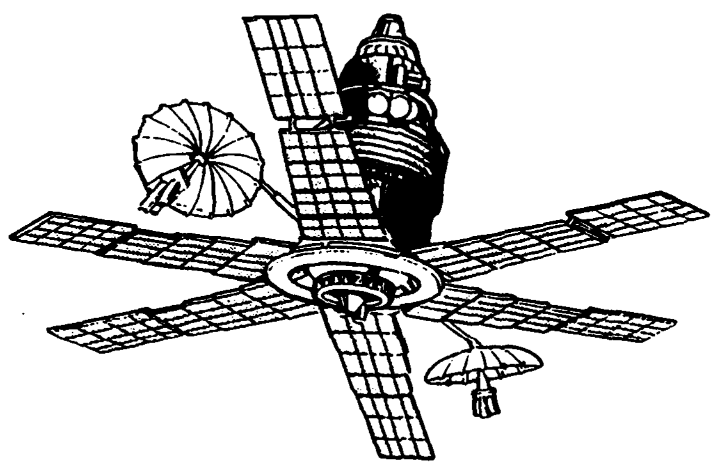

Figure 2-1 Molniya 1 Spacecraft (Johnson, 1991, p. 41)

Each spacecraft is launched with at least one transponder, normally operating in the 1.0 Ghz uplink and 0.8 Ghz downlink frequency bands.(Johnson, 1987, p.59) This gives the capability of one complete black and white television channel, as well as television audio, multichannel telephony, very high frequency (VHF) telegraphy, and photofacsimile. Some of the earlier spacecraft

carried cameras to provide a global view of the earth's dynamic atmosphere to augment the Meteor series of Russian weather satellites. As of this writing, Molniyas 1-85, 1-86, and 1-87 are on orbit.

Why are the Russians still using the first generation of Molniya spacecraft? Although it is 1960's technology, it has proven highly reliable, and is cost-effective off-the-shelf technology.

C. MOLNIYA 2

With the launch of the first Molniya 2 (1971-100A) from the Plesetsk Missile and Space Complex in November 1971, the first major changes, and possibly improvements in the Molniya system began. The Molniya 2 appeared to have some significant changes in size and configuration over the Molniya 1. The new three-section panel solar arrays produced 1 kilowatt of electrical power compared to the 500-700 watts of the Molniya 1's two-section arrays of the first generation Molniya. With the Molniya 2's upgrade in transponders and the new higher uplink and downlink frequency bands of 6 Ghz and 4 Ghz respectively, the Orbita stations were also upgraded to the Orbita-2 system.

This period in Soviet space development saw the USSR and eight Soviet bloc countries (Bulgaria, Cuba, Czechoslovakia, East Germany, Hungary, Mongolia, Poland and Romania) sign the Intersputnik agreement that was

the Communist response to the International Telecommunications Satellite (INTELSAT) organization.(Johnson, 1988, p.23)

That the Molniya 2 series was experimental is apparent form the short duration of use. The first Molniya was launched on November 24, 1971, and the seventeenth and final one was launched on February 11, 1977.

D. MOLNIYA 3

The Molniya 3 spacecraft (Figure 2-2) exhibits the same basic characteristics as its experimental predecessor, the Molniya 2. The first of the seemingly new series of communications satellites was launched from the Plesetsk Missile and Space Complex on November 2, 1974. The only visible improvement is the ability to relay color television, since the Molniya 1 and 2 could only broadcast in black and white.

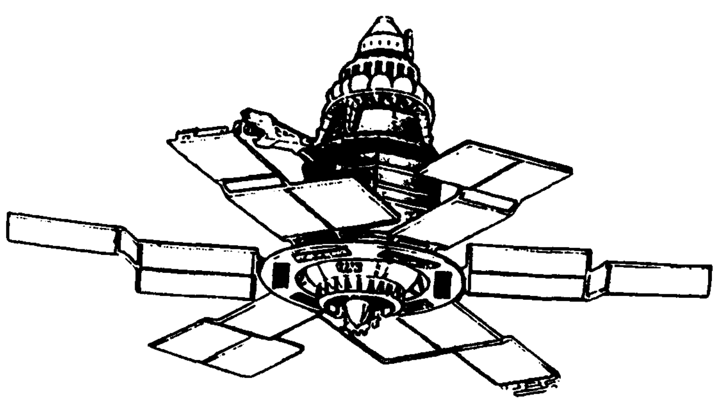

Figure 2-2. Molniya 3 Spacecraft (Johnson, 1991, p. 41)

There are three transponders in the 5.975 to 6.225 Ghz frequency band for uplink, and the 3.65-3.90 Ghz frequency band for downlink, with rated power of 40 watts (edge Effective Isotropic Radiated Power (EIRP) is 35 dBW).[Johnson, 1988, p.23] When the constellation of Molniya 3s was complete in 1975, the Molniya system consisted of 12 satellites, four each of the Molniyas 1, 2, and 3. For a period of time during the 1980's the Molniya 3 constellation was utilized as the spacebridge for the Moscow to Washington 'Hotline'.

The 'Hotline' utilizes two duplex telephone circuits with secondary telegraphic multiplexing. Messages from the United States to Moscow in English are transmitted via INTELSAT, and messages the other direction in Russian are via Molniya 3. The U.S. end of the Molniya 3 transmission is received at a Molniya station at Fort Dietrick, Maryland, and has been in operation since 1976. The Moscow end of this 'Hotline' is located in Vladimir, and has been disrupted occasionally by fire, pilfering, and the plow blade of a Finnish farmer.[Van Horn, p. 79]

Although the Molniya 3 system was intended to be a four-satellite constellation, interestingly the constellation swelled to eight satellites in the 1980's. Molniya 3s handle a major portion of the intra-Russian telephone and television traffic and a considerable portion of the international Russian

telephone and television traffic for the Russian Federation. However, the majority of international traffic is still funneled through the Gorizont system.

Table 2.1 is a listing of the classical elements for the current Molniya constellation. This table is current as of April 1994.

E. ORBITAL ANALYSIS

Table 2.2 contains the analysis results for the Molniya satellites. An "M" indicates that the majority (over 75%) of the observations were for midnight Greenwich Mean Time (GMT) only. An "N" indicates that the majority of the observations were for 1200 GMT only.

As should be expected from the highly elliptical Molniya orbit, availability was greatest in the regions near the central longitude of the Russian Federation. Specifically, phasic (all noon or midnight) observations were the norm for Bacolod, Republic of the Philippines, Kinshasa, Zaire, Kwajalein Atoll, and Lisbon, Portugal. As one would expect, locations within the Russian Federation and Commonwealth of Independent States experienced near continuous availability with Tekeli, Russia, experiencing an average of 80% availability and Vladivostok in the Far East experiencing an average of 72% availability. Notable exceptions to calling the Molniya system universally available are Dunedin, New Zealand, and Perth, Australia due to their extreme southern latitude. It is certain that with the use of U.S. relay satel-

lites, the Molniya constellation could be considered a reliable link in a disaster response satellite communication network for the northern hemisphere.

TABLE 2.1 MOLNIYA CLASSICAL ELEMENTS (NASA SATELLITE SITUATION REPORT)

	International Designator	Catalog Number	Launch Date	Period (Minutes)	Inclination (Degrees)	Apogee (Km)	Perigee (Km)
Molniya 1-85	1993-002A	22309	13 Jan 93	717.7	63.4	39822	528
Molniya 1-86	1993-035A	22617	26 May 93	717.8	62.9	39672	681
Molniya 1-87	1993-079A	22949	22 Dec 93	703.1	62.8	39188	437
Molniya 3-43	1992-085A	22255	2 Dec 92	717.6	63.3	39989	356
Molniya 3-44	1993-025A	22633	21 Apr 93	717.7	62.9	39603	744
Molniya 3-45	1993-049A	22729	4 Aug 93	717.7	62.8	39841	511

TABLE 2.2 MOLNIYA ANALYSIS RESULTS

	Molniya 1-85	Molniya 1-86	Molniya 1-87	Molniya 3-43	Molniya 3-44	Molniya 3-45
Bacolod	.5M	.5N	.5M	.02	.5M	.5N
Cape Town	.1	0	.12	.07	0	0
Colombo	.13N	.5N	.47	.08	.20	.5N
Dunedin	0	0	0	.05	0	0
Indian Ocean	0	0	.03	.1	0	0
Kinshasa	.5N	.5M	.5N	.03	.5N	.5N
Kwajalein	.5M	.5N	.5M	0	.5M	.5M
Lisbon	.5N	.5M	.68	.02	.72	1
Moscow	1	1	1	.12	1	1
Nairobi	.5N	.5M	.4	.07	.52	.5N
North Pole	1	1	1	1	1	1
Perth	0	0	.03	.08	0	0
Shemya	.77	.9	.53	.07	1	1
South Pole	0	0	.12	1	0	0
Tekeli	1	1	.83	.1	1	.87
Vladivostok	.7	.72	.88	.07	1	1

III. THE RADUGA (RAINBOW) SYSTEM

A. SYSTEM DESCRIPTION

The Raduga system was the predecessor for design and development of the Gorizont system. The first of the Raduga series, was launched on 22 December 1975 from Tyuratam Missile and Space Center, Kazakhstan. The overriding purpose of the new satellite communications systems was to provide uninterrupted telephone and telegraph radio communications utilizing C-band global, zonal and spot beams, and simultaneous transmission of color and black-and-white Central Television programs to the network of ORBITA stations. Uplink and down are reportedly provided by six traveling-wave-tube amplifiers (TWTA) with edge effective isotropic radiated power (EIRP) of 26 dBW global, 35 dBW zonal and 45 dBW zonal with circular polarization. Uplink and downlink are provide in the 5.75-6.25 Ghz and 3.42-3.92 Ghz frequency bands respectively. (Wilson, 1992, p. 411)

The first numbered satellite in the system, Raduga 1, was not launched until 21 June 89, with initial position at 49° East longitude. Subsequent launches have placed vehicles at 35, 45, 70, 85 and 128° East longitude and 25 and 170° West longitude. (Martin, 1991, p. 127) The Raduga bus is composed of a

power supply with sun-seeking guidance and tracking of solar cell batteries, three-axis stabilization, attitude and thermal control systems, as well as advanced communications for TT&C (telemetry, tracking and command). The communication of the Raduga system is limited to one television channel and approximately 10 duplex telephony/data channels capable of servicing 100 multiplexed telephone circuits, when used in conjunction with a 30- to 40-feet diameter earth station antenna. (Martin, 1991, p. 127)

The Raduga system's primary objective of government and military communications is accomplished with the Gals system. The Gals system consists of four communications packages similar to the U.S. military Defense Satellite Communications System (DSCS). The system uses the 7.9-8.4 Ghz frequency band for uplink and the 7.25-7.75 Ghz frequency band for downlink. Gals systems are primarily carried on Raduga buses at 25 and 170° West and 45 and 85° East longitude. Gals utilize ten narrowband channels, and three to four transceivers. (Martin, 1991, p. 129) Unconfirmed reports of 7/8-Ghz transponders from Raduga satellites raise the possibility of Gals systems at 35° East and 130° West, also. Patterns of coverage include earth coverage, Northern Hemisphere and a spot beam ($\approx 5°$ beamwidth). Gals has been estimated by some sources to also carry 150-300 watt 12 Ghz Ku-band transponders with a life of approximately 7 years. (Wilson, 1992, p. 408)

A transponder associated with Raduga based on geosynchronous orbit information filed with the International Frequency Registration Board (IFRB) is the Ultra High Frequency (UHF) Volna payload. The UHF Volna transponder is associated with odd-numbered Volnas and with corresponding longitudes for Raduga satellites. These uplinks are in the 335 to 400 MHz frequency band with downlink in the 240 to 328 MHz frequency band. According to Donald Martin of The Aerospace Corporation, this is an indication that "Raduga is the basic designation for synchronous orbit military/government communications satellites, and that each particular application (e.g., Volna) corresponds to a frequency band and a payload on the Raduga satellites." (Martin, 1991, p. 129) Details of the Volna system will be discussed in a later chapter.

Another transponder system which has been associated with the Raduga constellation is the Luch P system. Once again this is based on corresponding longitudes of the geosynchronous orbits for the Raduga satellites and filing with the IFRB for the Luch P system. The Luch system and the Luch P system will be discussed in a later chapter.

Are there commercial possibilities for the Raduga system? The answer is a solid yes, and the June 1993 issue of Satellite Communications explains why. Entrepreneur Ken Schaffer discovered himself on the receiving end of

Russia's Molniya broadcasting satellite, when searching for the Playboy channel with his satellite dish in 1982. The result is Belcom, Incorporated, which provides Western oil companies operating in remote regions of Russia and Kazakhstan with private satellite-based telecommunications services. Petronet, as it is called, "provides multiple channels for voice, fax and data communications via the Russian Raduga satellite at 35° East to connect remote oil sites to Belcom hubs in Helsinki and Moscow." (Hartshorn, 1992, p.36) Details are sketchy on the commercialization of Russian communications satellites, and the establishment of such networks takes time.

Greg Varisco, of IWL Communications in Houston, spent three years in Moscow setting up his company's service similar to Belcom's network. Even though Krasnoyarsk is still manufacturing and launching autonomously, the old Russian hierarchy makes cooperation difficult for Russians interested in commercializing space.

The classical elements for Radugas 16 through 1-2 are contained in Table 3.1

B. ORBITAL ANALYSIS

Tables 3.2 and 3.3 contain the results of the analysis of the Raduga constellation. As previously explained, "M" denotes a majority of midnight GMT

observations, and "N" denotes a majority of 1200 GMT observations. Due to large number of satellites in the Raduga constellation, a unit of comparison called the Constellation Wide Usability (CWU) was used. This unit indicates the average usability percentage of all satellites in the constellation for that location. A CWU of 100% would indicate that all of the satellites in the constellation were usable from that location at each time analyzed. For purposes of this analysis, a CWU below 75% would be considered below average.

With certainty, locations with a longitude within 20° of the longitude of the ascending node of each satellite in the constellation experienced great usability (available 80% of the simulated time). The central Russian longitude of the Radugas 18, 19, 20 made them more usable than the newer members of the constellation, which are spread over the Russian landscape and provide services to or between specific areas. Viewing the constellation as a whole, Bacolod, Republic of the Philippines (81% constellation wide usability (CWU)), Cape Town , South Africa (81% CWU), Kinshasa, Zaire (80% CWU), Moscow, Russia (77% CWU), the North Pole (95% CWU), Nairobi, Kenya (80% CWU) and the South Pole (100% CWU) showed best overall constellation availability.

Of note are the analyses from the moderately extreme locations. Dundedin, New Zealand, was above 50% in usability for Radugas 18, 19, and 20,

but was unusable to the rest of the constellation. For comparison, this gives a CWU of 22%. Shemya, Alaska exhibited the same usability to Radugas 18, 19, and 20, as did Dunedin, with the addition of Raduga 27. This addition is probably due to Shemya's longitude and the longitude of the ascending node of Raduga 27. As was the case with Dunedin, Shemya's CWU was well below 50%, at 20%.

Finally, there is the results from Kwajalein Atoll. Near the midpoint of the Pacific Ocean, it was considered indicative of equatorial sites, but this proved to be untrue when compared with the results for Kinshasa, Zaire and Nairobi, Kenya both of which had a CWU of 80%. Kwajalein Atoll showed particularly good usability for Raduga 17, 19, and 20, but exhibited an overall CWU of 26%.

With the use of relay satellites, the Raduga constellation could be used to provide worldwide coverage if needed. The preponderance of transponders this spacecraft carries make it a major player in Russia's bid for a place in the global communications market.

TABLE 3.1 RADUGA CLASSICAL ELEMENTS

Raduga	International Designator	Catalog Number	Launch Date	Period (Minutes)	Inclination (Degrees)	Apogee (Km)	Perigee (Km)
16	1985-070A	15496	8 AUG 85	1434.9	6.1	35768	35757
17	1985-107A	16250	15 NOV 85	1438.0	5.8	35783	35774
18	1986-007A	16497	17 JAN 86	1457.3	5.8	36493	35909
19	1986-082A	17046	25 OCT 86	1462.6	5.1	36353	36252
20	1987-028A	17611	19 MAR 87	1500.6	5.1	37159	36922
21	1987-100A	18631	10 DEC 87	1436.4	3.9	35793	35789
22	1988-095A	19596	20 OCT 88	1436.4	2.9	35798	35784
23	1989-030A	19928	14 APR 89	1436.0	2.6	35789	35781
1-1	1989-048A	20083	21 JUN 89	1436.2	2.5	35796	35781
24	1989-098A	20367	15 DEC 89	1436.8	1.9	35813	35786
25	1990-016A	20499	15 FEB 90	1436.1	1.7	35795	35779
26	1990-112A	21016	20 DEC 90	1436.9	1.0	35826	35777
1-2	1990-116A	21038	27 DEC 90	1436.3	1.0	35798	35781
27	1991-014A	21132	28 FEB 91	1436.1	1.1	35800	35773
28	1991-087A	21821	19 DEC 91	1436.3	0.1	35798	35783
29	1993-013A	22557	25 MAR 93	1436.3	1.0	35802	.5778
30	1993-062A	22836	30 SEP 93	1436.0	1.3	35816	35754
31	1994-012A	23010		1435.7	1.4185	35826	35733

TABLE 3.2 ANALYSIS RESULTS FOR RADUGAS 16-25

Raduga	16	17	18	19	20	21	22	23	24	25
Bacolod	.5M	1	.55	1	.68	1	.5M	.5M	1	1
Cape Town	1	0	1	1	.55	0	1	1	1	1
Colombo	0	0	.38	.73	.4	0	1	0	1	1
Dunedin	0	1	1	.43	.6	1	0	0	0	0
Indian Ocean	0	0	.35	.72	.38	0	1	0	1	1
Kinshasa	1	0	.8	1	.55	0	1	1	1	1
Kwajalein	0	1	0	.28	.35	1	1	0	0	0
Lisbon	1	0	1	.67	.58	0	1	1	1	0
Moscow	1	0	.62	.77	.43	0	1	1	1	1
Nairobi	1	0	.66	1	.5	0	1	1	1	1
North Pole	1	1	.03	1	1	1	1	1	1	1
Perth	0	1	.15	.53	.35	.52	0	0	1	1
Shemya	0	1	0	.22	.33	1	0	0	0	0
South Pole	1	1	1	1	1	1	1	1	1	1
Tekeli, Russia	0	0	.36	.72	.4	0	1	0	.1	1
Vladivostok	0	1	.03	.45	.66	1	0	0	.2	1

TABLE 3.3 ANALYSIS RESULTS FOR RADUGAS 26-31

Raduga	26	27	28	29	30	31	1-1	1-2	CWU
Bacolod	1	1	.5M	.5M	1	1	1	1	81
Cape Town	1	1	0	1	1	1	1	1	81
Colombo	1	1	1	1	1	1	1	1	70
Dunedin	0	0	0	0	0	0	0	0	22
Indian Ocean	1	1	1	1	1	1	1	1	70
Kinshasa	1	0	1	1	1	1	1	1	80
Kwajalein	0	1	0	0	0	0	0	0	26
Lisbon	0	1	0	1	1	0	.5	1	65
Moscow	1	0	1	1	1	1	1	1	77
Nairobi	1	0	1	1	1	1	1	1	80
North Pole	1	1	1	1	1	1	1	1	95
Perth	1	1	1	0	1	1	1	1	64
Shemya	0	1	0	0	0	0	0	0	20
South Pole	1	1	1	1	1	1	1	1	100
Tekeli, Russia	1	1	1	1	1	1	1	1	64
Vladivostok	0	1	0	0	1	1	1	0	46

IV. THE GORIZONT SYSTEM

A. SYSTEM DESCRIPTION

The first of thirty satellites in the Gorizont ("Horizon") series was launched on December 19, 1978 with an inclination of 11.3 degrees and an orbital period of 24 hours. Since the orbit filed with the International Frequency Registration Board (IFRB) indicated the spacecraft would occupy a Soviet global geostationary satellite position, or Statsionar (Russian for "stationary"), the Gorizont satellite was not considered a part of the Statsionar system until the third launch. The orbit inclination of 11.3° of the first vehicle was attributed to a launch vehicle malfunction. (Martin, p. 127, 1991) The second spacecraft in the series was eventually corrected from a geosynchronous into a geostationary orbit with multiple ground-controlled maneuvers. The third satellite, launched on December 29, 1979, was inserted into a Statsionar orbit immediately. The initial three satellites of the series were utilized to provide television coverage of the 1980 Olympic Games from Moscow. The original configuration, as illustrated in Figure 4-1 has changed little since the launch of the initial spacecraft.

Far from its humble origins, Gorizont currently carries the US/Russian "Hotline" as well as providing TV distribution via the Moskva system, inter

Figure 4.1 The Gorizont spacecraft (Johnson, 1991, p. 46)

national Intersputnik telecommunications services, and the International Maritime Satellite (INMARSAT) maritime/aeronautical communications network. The heart of the Intersputnik network, Gorizont connects major ground stations in 16 countries throughout Europe, Asia and Africa using 100 international voice-grade circuits utilizing the International Telecommunications Satellite (INTELSAT) network.

Follow-on launches placed space vehicles (SV) in near-geosynchronous orbits with an inclination of 1.5 degrees at beginning of life. Details of individual orbits and North American Air Defense Command (NORAD) two-line orbital elements (TLE) are listed in Table 4.1. In general, Gorizonts are

launched into one of ten orbital locations which have been registered with the International Frequency Registration Board (IFRB) of the International Telecommunications Union (ITU). Filings with the IFRB/ITU list the system's purpose as domestic use by the National Satellite System. The ten orbital locations in the Statsionar system are located at 14°, 11°W, and 40°, 53°, 80°, 90°, 96.5°, 103°, 140°, and 145°E.

Gorizont satellites carry three transponder payloads. The first consists of six transponders in the 6/4 Ghz frequency band and are called Statsionar. Additionally, Volna transponders, cross-strapped on the Statsionar, operate

TABLE 4.1 GORIZONT CONSTELLATION GENERAL DESCRIPTION

Gorizont	International Designator	Catalog Number	Launch Date	Period (Minutes)	Inclination (Degrees)	Apogee (Km)	Perigee (Km)
11	1985-007A	15484	18 JAN 85	1435.3	6.3	35790	35750
#12	1986-044A	16769	10 JUN 86	1435.1	5.1	35796	35736
13	1986-090A	17083	18 NOV 86	1488.8	4.9	36880	36743
14	1987-040A	17969	11 MAY 87	1474.6	6.6	36658	36416
15	1988-028A	19017	31 MAR 88	1472.0	3.7	36630	36343
16	1988-071A	19397	18 AUG 88	1440.3	3.2	35919	35816
17	1989-004A	19765	26 JAN 89	1436.1	2.8	35788	35783
18	1989-052A	20107	5 JUL 89	1436.3	2.4	35798	35782
19	1989-081A	20263	28 SEP 89	1436.1	2.3	35788	35785
20	1990-054A	20659	20 JUN 90	1436.1	1.5	35801	35771
21	1990-094A	20923	3 NOV 90	1436.0	1.3	35788	35780
22	1990-102A	20953	23 NOV 90	1436.2	1.2	35794	35781
23	1991-046A	21533	1 JUL 91	1455.9	0.5	36198	36148
24	1991-074A	21759	23 OCT 91	1436.1	0.3	35802	35771
25	1992-017A	21922	2 APR 92	1436.0	0.2	35787	35783
26	1992-043A	22041	14 JUL 92	1436.2	0.5	35799	35777
27	1992-082A	22245	27 NOV 92	1436.0	0.6	35794	35774
28	1993-069A	35752	28 OCT 93	1435.3	1.5	35789	35752
29	1993-072A	22907	18 NOV 93	1432.4	1.5	35782	35554

*SATELLITES HAVE BEEN MOVED OUT OF SYNCHRONOUS ORBIT
#ARE PROBABLY NO LONGER WORKING

in the 6/1.5 Ghz and 1.6/4 Ghz frequency band. This approach enables links between shipborne mobile facilities and terrestrial ground facilities. The final transponder package, Luch, operates in the 14/11 Ghz frequency band as part of the Satellite Data Relay Network (SDRN).

The Statsionar (or Gorizont) transponders utilize five 15-watt transponders and a single 40-watt transponder to provide multi-purpose service, with the lowest frequency transponder (and the highest power transponder (40W)) providing an effective isotropic radiated power (EIRP) of 46 dBW to simplified 2.5 meter Moskva television receiving stations.[(Commercial, 1993, p. 53)] This 40-watt transponder also utilizes a five-by-five degree zonal beam and a bandwidth of 40 MHz (the other transponders have a bandwidth of only 34 MHz).

The Volna transponders are to Gorizont what the INMARSAT package is to INTELSAT 5 F5-9 . Volna (Russian for "wave") is an eight system special communications package that provides shipborne and airborne mobile communications via Orion ground stations and Volna-S shipboard stations. Maritime service is provide by Volna 1/2/4/8 in the 1636-1644 MHz band for uplink and 1535-1558 MHz band for downlink. Aeronautical services are provided by Volna 1/2/4/8 at 1645-1660 MHz uplink and 1543-1558 MHz downlink. Volna 1/3/5/7 (probably associated with the Raduga bus) utilize the same frequencies as mentioned above with the addition of a 335-399 MHz

uplink and a 240-328 MHz downlink. While the majority of the Volna system utilizes Gorizont as a host, "special" UHF transponders will probably use the Raduga as their host satellite.(Van Horn, 1992, p. 73)

The Loutch (or Luch which means Beam or Ray in Russian), is a communications service and a spacecraft. The initial four Luch systems were flown as transponders on Gorizont satellites and were used for a series of communications and propagation experiments. The Luch transponders (and eventually the satellite system) are designed to provide two-way television data exchange between ground control stations (GCS) and the Mir orbital station. Luch utilizes ten transponders in the fixed-satellite service subbands (10.95-11.2 Ghz and 11.45-11.7 Ghz). Transponder bandwidth is 34 MHz, with a center frequency separation of 50 MHz. The Luch spacecraft (Russian "TDRS-ski") will be discussed in a later chapter.

Gorizont spacecraft and communications services are now being offered commercially. Spacecraft would be placed in customer specified orbits by means of three available launch vehicles, but primarily by PROTON. "The telecommunications satellite is being offered for commercial use by Glavcosmos and V/O Licensintorg." (Lenorovitz, 1987, p. 22) Contract details will be handled by V/O Licensintorg, and technical details by Glavcosmos. A typical communi-

cations launch on PROTON would cost approximately $24 million , payable only in Swiss francs. (Lenorovitz, 1987, p. 22)

Outside the 18 Gorizonts that are deemed to still be operational (11 and 13-29), two Gorizont vehicles were to be launched in 1993 as Rimsat 1 and Rimsat 2 for lease to the Republic of Tonga. A third Rimsat is predicted by the Department of Commerce, Office of Telecommunications in September 1994, but it is expected to be an Express space vehicle.

The commercial expansion of the Gorizont system is a proof of concept for the emerging satellite industry at K-26 (Satellite City), Siberia. The Gorizonts have proven to be a highly reliable, low-risk communications platform with an estimated life of five years. Russian satellite research and development headed by Sergei Korolev at the Propulsion and Rocket Development Institute are working to improve the reliability and lifetime of the Gorziont. Why? The basic bus for the Gorizont and the follow-on Express are the same with the only major differences in antennae and transponders (TWTAs are virtually identical to the Gorizont). (Filep, 1993, p. 26) Increased reliability and lifetime for the Gorizont will ensure competitiveness of the Express in Western and Asian communications markets. This claim of high reliability of the Gorizont bus runs counter to reports from the highest Russian government levels that the Gorziont system (as well as the Ekran system) are "short-lived,

under-equipped, power-wasteful, and incapable of maintaining a stable orbit." (Russian, 1993, p. 2) And predictions are that the Express represents only minor improvements.

A final system which can be linked to the Gorizont space vehicle by virtue of coincident longitudes, is the Romantis. The Romantis system was introduced at the Second European Conference on Satellite Communications in Liege, Belgium, in 1991. As a then Soviet-German cooperative effort, it was seen as a means for achieving "comprehensive improvement of the communications infrastructure in the whole territory of the USSR with a reasonably short time frame."(Frederichs, 1991, p. 29)

The system is touted as extremely flexible to allow for adaptation for regional systems as well as international traffic. Digital voice (32 kbps) and data services (64-2048 kbps) are provided via frequency demand multiple access/single channel per carrier (FDMA/SCPC) and demand assignment multiple access (DAMA) techniques. (Frederichs, 1991, p. 29) Uplinks will be provided in the 12.75-13.25 MHz frequency band, with downlink services in either the 10.7 to 10.95 MHz or 11.2-11.45 MHz frequency bands. The transmission bandwidth is broken into six channels, each with 72 MHz of useful bandwidth. The uplink segment further divides two of the 72 MHz channels into

"four 36 MHz wide channels which are used for inter-beam communications." (Frederichs, 1991, p. 29)

The FDMA/SCPC mode for voice and data is expected to provide 16,000 duplex channels per satellite, with the DAMA technique providing 320,000 users per satellite. (Frederichs, 1991, p. 29)

This system's dependence on small, inexpensive ground stations is intended to make the maximum use of available technology and little reliance on research and development. Mass production at a reasonable cost seems to be the key to this system providing a panacea for the Russian Federation's communications problems. The income from commercial ventures may make improving the system less painful.

California-based IDB Communications is taking on the banking and oil industries in the area of private networks. Additionally, they are raising the hackles of such telecommunications giants such as AT&T, Nokia, MCI and US West in the long distance telephone arena. IDB offers private line, voice and data, switched service and television via the Gorizont system. More than fifty percent of IDB's business is public switched telephone network services. To accomplish this, IDB has established operating agreements with "18 companies in Russia, Kazakhstan and Azerbaijan; the clients include earth station operators, satellite space segment operators, microwave companies and

local telephone companies." (Hartshorn, 1993, p. 38) With time, patience, and speaking Russian, the possibilities are endless.

Gorizont pricing is considered mid-range by market standards. Gorizont spacecraft currently on orbit at 40°,103°, and 140° East can be leased for \$1.3-\$1.5 million , depending upon specific service details. Unlaunched Gorizont spacecraft can also be leased, including launch services. The Rimsat company, a U.S.-Russian joint venture recently celebrated the successful launch of the first of seven leased Gorizont spacecraft, designed to provide communications services to consumers in India, China, Australia and New Zealand. Michael Steinberg, a Rimsat company leader stated that " the launching of this satellite (the first in the series of seven) proves that Russia is a reliable supplier of sophisticated equipment."(Nadein, 1993, p. 3)

B. ORBITAL ANALYSIS

Due to large number of satellites in the Gorizont constellation, the same unit of comparison used for the Raduga analysis, the Constellation Wide Usability (CWU) was used. This unit indicates the average usability percentage of all satellites in the constellation for that location. A CWU of 100% would indicate that all of the satellites in the constellation were usable from that location at all times analyzed. For purposes of this analysis, a CWU below

75% would be considered below average. As previously stated, "N" denotes predominantly 1200 Greenwich Mean Time (GMT)observations and "M" denotes predominantly midnight GMT observations.

The results of the Gorizont analysis is contained in Table 4.2. With an average CWU of 75%, there were only 6 of the 19 satellites that were below the average, notably, Cape Town, South Africa; Dunedin, New Zealand; Kinshasa, Zaire; Lisbon, Portugal; Moscow, Russia; Nairobi, Kenya; and Shemya, Alaska. The worst of these was Lisbon, with a CWU of 24%.

It might seem odd that Moscow was below the average with a CWU of 49%, but this is easily explainable. As mentioned in Chapter I, the Russian Federation is a large landmass. As such, satellites are placed in orbit to service specific geographic regions. Satellites not in an orbit with a longitude of the ascending node that is within 20° of the longitude of Moscow would provide only limited service to Moscow.

It is evident from the data in Table 4.2, that the Gorizont constellation is primarily designed to service Russia east of the Ural mountains. Bacolod, Republic of the Philippines (CWU 69%), Colombo, Sri Lanka (78%), and Vladivostok, Russia (73%) are supportive of this.

As a whole, the Gorizont constellation appears to be usable at most latitudes and longitudes, and could be considered a reliable link in a natural disaster communication system.

TABLE 4.2 GORIZONT SYSTEM ANALYSIS

	11	12	13	14	15	16	17	18	19	20
Bacolod	1	.5M	.5N	.5M	.2N	.5M	.3N	.5M	1	.5M
Cape Town	1	1	1	.33	.45	.05	0	0	1	1
Colombo	1	1	.42	.55	.62	1	1	1	1	0
Dunedin	.73	1	.42	.3	.38	1	1	1	1	0
Indian Ocean	1	1	.4	.58	.58	1	1	1	1	0
Kinshasa	0	0	.42	.33	.46	0	0	0	1	1
Kwajalein	1	1	.43	.58	.6	1	1	1	1	0
Lisbon	0	0	.42	.32	.37	0	0	0	0	1
Moscow	.08	0	.4	.36	.53	.5	0	0	1	1
Nairobi	.12	0	.43	.4	.55	.68	0	0	1	1
North Pole	1	1	1	1	1	1	1	1	1	1
Perth	1	1	.22	.56	.6	1	1	1	1	0
Shemya	1	1	.4	.53	.55	1	1	1	0	0
South Pole	1	1	1	1	1	1	1	1	1	1
Tekeli	1	1	.42	.53	.6	1	1	1	1	0
Vladivostok	1	1	.43	.55	.60	1	1	1	1	0

TABLE 4.2 GORIZONT SYSTEM ANALYSIS(Continued)

	21	22	23	24	25	26	27	28	29
Bacolod	1	.5M	.93	1	1	.58	.53	1	1
Cape Town	.5M	1	.12	1	1	.33	.38	1	0
Colombo	1	1	.53	1	1	.36	.3	1	1
Dunedin	.5M	0	.55	0	1	.22	.26	0	1
Indian Ocean	.5M	1	.52	1	1	.1	.13	1	1
Kinshasa	1	1	.1	1	0	.42	.42	1	0
Kwajalein	.27	0	1	0	1	.43	.5M	1	1
Lisbon	.5	1	0	0	0	.45	.43	0	0
Moscow	.5	1	.22	1	1	.45	.35	1	0
Nairobi	.88	1	.25	1	1	.38	.4	1	0
North Pole	1	1	1	1	1	1	1	1	1
Perth	1	0	1	1	1	.2	.27	1	1
Shemya	.52	0	.92	0	1	.48	.37	0	1
South Pole	.5M	1	1	1	1	.3	.62	1	1
Tekeli	.52	1	.52	1	1	.58	.25	1	1
Vladivostok	.5N	0	.87	1	1	.57	.4	1	1

V. THE LOUTCH (BEAM) SYSTEM

The Loutch (or sometimes spelled Luch) was previously discussed as a satellite service on the Gorizont and Raduga "host" satellites. This chapter will deal with the Loutch system and associated spacecraft as they relate to the Russian vision of a satellite data relay network (SDRN).

Loutch was initially used by the Soviet Union to experiment with the possibility of a Ku-band Russian domestic television service. Initial trials involved the downlink of an unmodulated beacon at 11.541 Ghz and sporadic Russian television broadcasts at 11.525 Ghz.[(Hollansworth, 1994)]

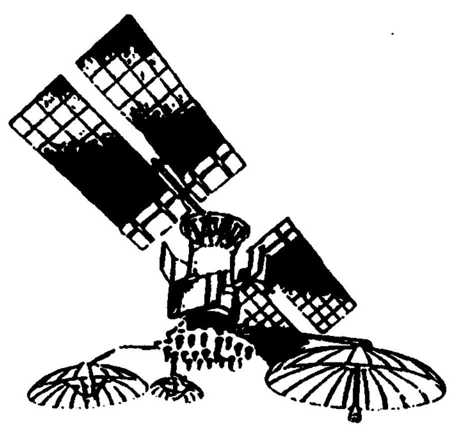

Figure 5-1. The LOUTCH Spacecraft[(Johnson, 1991, p. 48)]

The system is primarily designed to provide communications and control for low-earth orbit satellites, as well as provide duplex television data ex-

change between the MIR orbital station and ground control stations. Additionally, the Loutch system will provide :

-teleconferencing services worldwide;

-real-time television telecasts;

-two-way exchange of video information and organization of television bridges; and

-organization of telephone and communications services during natural and man-made disasters in remote regions inside and outside of the Russian Republic.

The satellite networks, as registered with the IFRB ITU, are divided into an eastern (ESDRN-160° W), western (WSDRN-16° W) and central (CSDRN-95° E) sectors. As of March 1993, only the CSDRN-95° E (Cosmos 1897) and WSDRN-16° W (Cosmos 2054) locations are operational. (Commercial, 1993, p. 54)

As registered, the Loutch systems have ten transponders in the fixed-satellite service subbands. Spacecraft to spacecraft uplink and downlink are at 15.05 Ghz and 13.52 Ghz respectively, with a nominal bandwidth of 34 MHz. Tracking, telemetry and control (TT&C) with the Moscow and Khabarovsk ground stations is accomplished at 10.82, 11.32 and 13.7 Ghz. (Van Horn, 1985, p. 76) Uplink from ground stations is at 14.62 Ghz. All operating frequencies fall well within international fixed satellite service subbands which

are also used by INTELSAT and European Communications Satellites (ECS, or European Telecommunications Satellites -EUTELSAT) satellites.

Currently, TV-exchange traffic between low-orbital shuttle and ground control sites is limited to about ten sessions per month, with an average of 30 minutes per session. The WSDRN-16° W has recently been made commercially available to provide video, audio and data connectivity under a joint venture between Transworld Communications, Washington InternaO tional Teleport and Ostankino (formerly Gostelradio). (Boeke, 1993, p. 60) Ostankino is presently providing broadcast television programming and services in the Commonwealth of Independent States (CIS). Transworld, as manager of the joint effort, is providing a 36 MHz and a 54 MHz transponder for linking points in the United States east of Detroit, Central and South America, Europe , Africa and the Middle East. For a tariff of $1,950, Transworld will provide uplink services on the Russian side, full space segment (15 minute increments), and downlink services at Washington International Teleport. If this venture is successful, other SDRN satellites (possibly at 95° E and 200° E) could be available in the near future. The centralization of control of services at each end of the space segment, Moscow and Washington, DC, gives this venture limited flexibility.

There are no available two-line elements for the Luch spacecraft, and there have been no confirmed vehicles on orbit. The Luch transponders on Gorizont spacecraft continue to operate normally.

VI. EKRAN (MOVIE SCREEN)

A. SYSTEM DESCRIPTION

Though the ORBITA system, as discussed previously, was cheaper than a terrestrial television, the cost and complexity of the receiving stations made it impractical. Thus was born the idea for the EKRAN system (Figure 6-1). The Ekran system, also known as Statsionar T from its International Frequency Registration Board filing, provides television direct broadcast services (DBS) to remote small communities in the Russian Far East and northern areas. Service is not available to the Kamchatka peninsula or Chukotka due to International Telecommunications Union (ITU) constraints on levels of power flux density in bordering countries. Though the coverage area is limited, the current Ekran-M system provides direct broadcast television to over 20 million viewers, "of whom some 7.7 million could not receive TV before the Ekran system was established." (Commercial, 1993, p. 59) With a service area of over nine million square kilometers, this system is the lifeblood of news, information and entertainment for some of the remotest regions of the Russian Federation.

The early EKRAN system made use of a single frequency transponder, downlinking at 714 MHz. Receivers on the ground made use of simple and inexpensive receivers and Yagi antennas. Produced by the Ministry of the Communications Equipment, receiving stations fall into two categories. The first category are considered professional stations (designated STV-100), and use 32 or 16 element antennas yielding a signal-to-noise ratio (SNR) of approximately 55 dB. The broadcast is further distributed through local TV centers and high power repeaters.

The second category, designated STV-1, feed repeaters for cable distribution networks and low power repeaters. Their four element antennas yield an SNR of 48 dB. Uplink to the satellite for DBS is accomplished with 12 meter antennas (antenna gain is 54 dB at 6 Ghz) and 10 kilowatt transmitters. (Commercial, 1993, p. 59)

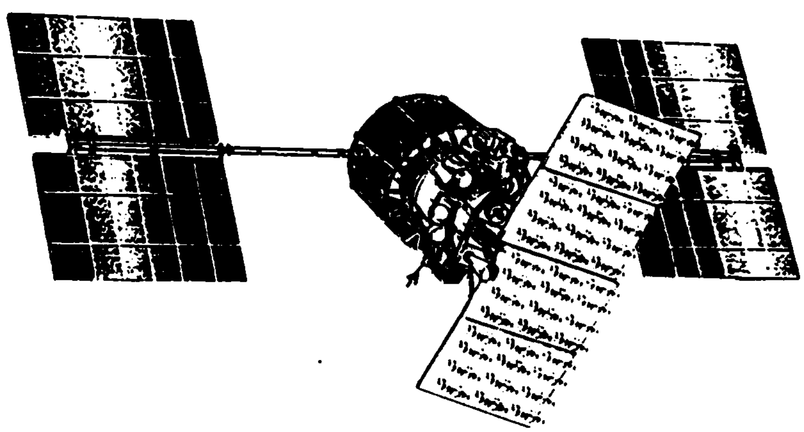

Figure 6-1. Ekran spacecraft (Johnson, 1991, p. 45)

The Ekran-M spacecraft, introduced in 1989, make use of a second 200 watt transponder operating at 754 MHz. Each of the spacecraft, Ekran and Ekran-M, use 96-element helical antennas with peak antenna gain of 33.5 dB and edge EIRP of 26 dB.(Martin, 1990, p. 127)

The Ekran/Ekran-M system normally consists of two satellites co-located in geostationary orbit at 99° East. Currently Ekrans 17, 19 and 20 are on orbit. Though the Ekran system has proved to be long-lived and reliable it was replaced by the Gals/Gelikon system in 1991/2. This new Gals/Gelikon system has been designated STV-12, and operates in the 11.7-12.5 Ghz frequency band, with a projected capacity of 12 transponders. (Commercial, 1993, p. 59)

Classical orbital elements for all Ekran spacecraft through Ekran 20 are contained in Table 6.1

B. ORBITAL ANALYSIS

As Table 6.2 indicates, the Ekran system is visible from all locations tested, with the exceptions of Ekran 20 at Cape Town, South Africa, Ekran S 19 and 20 at Lisbon, Portugal, and Ekran 19 at Shemya, Alaska. The results for Kinshasa, Zaire, and Cape Town, South Africa, are confirmed by other sources. Wilson Space Directory reports that the "TV transmissions have been resolved experimentally in Malawi and South Africa, some 13 degrees off beam, a direction in which EIRP is estimated as 30 dBW. (Van Horn, 1992, p. 76)

TABLE 6.1 EKRAN SATELLITE CONSTELLATION

EKRAN	INTERNATIONAL DESIGNATOR	CATALOG NUMBER	LAUNCH DATE	PERIOD (MINUTES)	INCLIN. (DEG)	APOGEE (Km)	PERIGE E (Km)
17	1987-109A	18715	27 DEC 87	1501.9	3.6	37239	36890
19	1988-108A	19683	10 DEC 88	1436.3	2.9	35804	35778
20	1992-074A	22210	30 OCT 92	1436.3	0.7	35803	35778

TABLE 6.2 EKRAN ANALYSIS

Ekran	**17**	**19**	**20**
Bacolod			
Cape Town	.56	1	0
Colombo	.45	.5M	1
Dunedin	.52	1	1
Indian Ocean	..42	1	1
Kinshasa	.58	1	0
Kwajalein	.35	1	1
Lisbon	.6	0	0
Moscow	.52	1	1
Nairobi	.55	1	1
North Pole	.36	1	1
Perth	.33	1	1
Shemya	1	0	1
South Pole	.35	1	1
Tekeli	.43	1	1
Vladivostok	1	1	1

VII. FUTURE AND MISCELLANEOUS SYSTEMS

A. OVERVIEW

The Russian Federation/CIS are in a state of flux at present with an endless stream of carpetbaggers from the West bringing dreams of global connectivity, and the scientists at Krasnoyarsk pumping out satellites and plans for new satellite systems as though there were another space race occurring. This chapter is an attempt to look at some of the current and proposed systems, as well as ground support systems and satellite communications users. For purposes of this chapter, satellite communications will encompass telephony, telegraph, television, TT&C, as well as navigational information. Since satellite communication is a dynamic industry, this chapter is not comprehensive in its coverage or information.

B. ARCOS

Arcos (Figure 7-1) is derived from the Gals system, and is intended as a three-member constellation at 85°, 190°, and 346° East. The C- and L-band transponders provide mobile communications to users on air, land or sea. The first Arcos was expected to be launched in 1993, with mass, electrical

power and design life the same as Gals, but with slightly different dimensions. (Johnson, 1991, p. 50)

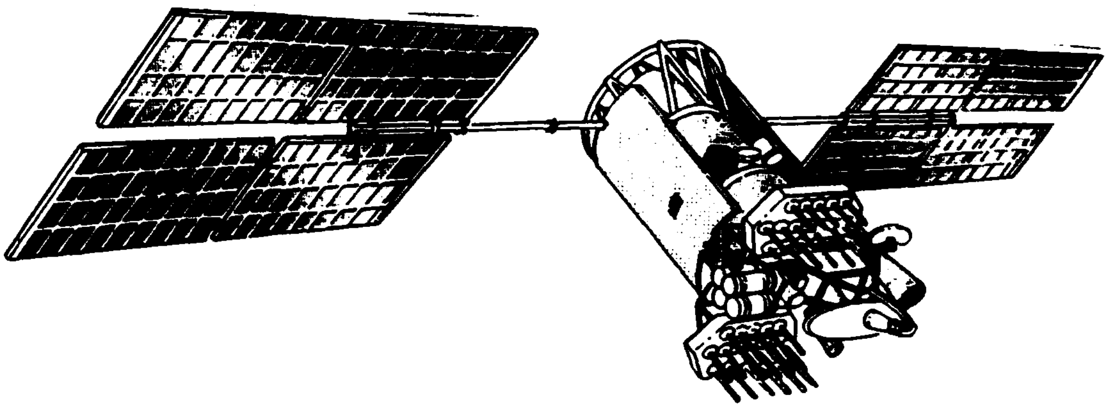

Figure 7-1. The Arcos Spacecraft (Johnson, 1991, p. 51)

C. BANKIR

Initial launch for the Bankir system is set for 1993-94. The system's messaging communications services in the 400 to 800 MHz frequency band will handle up to 10,000 messages of approximately 400 characters each. The bus will be derived from Lavotchkin's Phobos and microgravity craft. (Wilson, 1992, p. 408)

D. GLONASS

Just as no discussion of US communications satellites is complete without mentioning NAVSTAR/GPS, no discussion of Russian communications satellites is complete without mentioning Glonass (Global Navigation Satel-

lite System). It is possible to call Glonass (Figure 7-2) the GPS-sky, since it is a virtual carbon copy of GPS. Operating at center frequencies of 1250 MHz and 1603.5 MHz, the system provides navigation accuracy approximating that of its American counterpart.

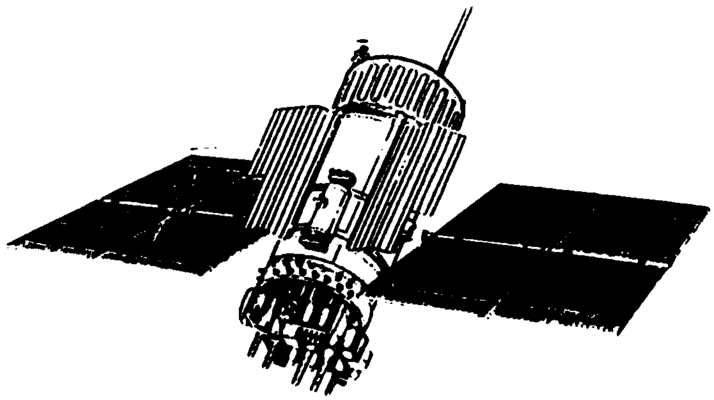

Figure 7-2. The Glonass Spacecraft (Johnson, 1991, p. 56)

Where GPS leaves off, Glonass picks up. A special maritime receiver, named Shkiper, can "calculate the distance traveled from origin or another point, the distance between two points enroute, and recommended courses to a destination and arrival time at a set speed" in addition to calculating ship's position and velocity. (Johnson, 1991, p. 55) Accuracy using the SHKIPER is within 100 meters of latitude or longitude, 150 meters altitude, and plus or minus 15 centimeters per second.

The great similarities between the NAVSTAR/GPS system and Glonass has been quickly exploited by Western capitalism. Northwest Airlines and

Hon‹ ‸ ⁻well have implemented a unified Glonass-GPS network, after squelching objections from the Department of Defense. This may provide a larger constellation, and thus better overall resolution, but reliance on Glonass as a primary source could be a mistake. The scientific community has taken exception to the Glonass constellations continual interference with radio astronomy. (Cohen, 1990, p. 91-93) It has been noted that even though each vehicle transmits on a different frequency in the 1597-1617 MHz frequency band, transmissions in the 1607-1612 MHz frequency band "can overwhelm naturally occurring emissions outside our solar system associated with the hydroxyl molecule. (Johnson, 1991, p. 56) There are no indications yet if the fully operational constellation is detrimental to the investigation of the electromagnetic cosmos.

E. GALS/GELIKON

Gals and Gelikon will be the cornerstone of the new Russian direct broadcast system (DBS). It is anticipated that with the complete deployment of the Gelikon constellation (six space vehicles) at the end of 1995, the network will support an independent Russian communications system. The advantage of Gelikon over Ekran is an improved Ku-band transponder with

power output of approximately 150-300 watts and an estimated seven year life. (Johnson, 1991, p. 50)

Locations for Gals spacecraft (Figure 7-3) have been identified as 23° and 44° East. With an operational life of seven years and three Ku-band transponders, Gals will complete the DBS constellation.

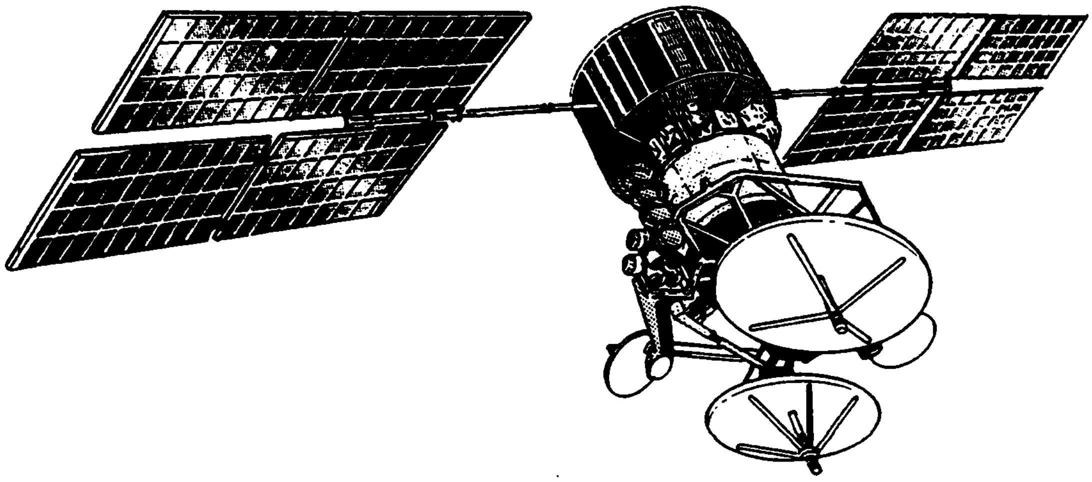

Figure 7-3. The Gals Spacecraft (Johnson, 1991, p. 51)

F. INFORMATOR

Informator was intended as a store and forward satellite to relay geologic data and to provide communications for survey parties' disaster relief operations. The first spacecraft was launched as an experiment in January 1991, with an expected life of three years. An RS-14 transponder for the Soviet AMSAT (Amateur Satellite) was a hitchhiker on the flight. The sys-

tem uses five mobile ground stations, four in Krasnoyarsk and one in Archangelsk. No further information is available.

G. INTERSPUTNIK

The Director General of Intersputnik, Genady Kudryavtsev, states InterSputnik's "main task is to render assistance to the former Soviet republics in establishing direct international links with foreign partners." (Upfront 1993, p. 26) Under its constitution signed by member states (the then USSR, Afghanistan, Bulgaria, Hungary, Vietnam, Germany, Yemen, North Korea, Cuba, Laos, Mongolia, Nicaragua, Poland, Romania, and Czechoslovakia), Intersputnik provided satellite-based TV, radio, telephony, and data links. With the breakup of the Soviet Union, and the emergence of INTELSAT and INMARSAT in global satellite communications, this centralized Russian-run communications network is striving to find new markets.

What satellites comprise the Intersputnik network? Gorizont spacecraft primarily. However with the advent of the Ekran system for providing direct broadcast television, as well as the follow-on Gals/Gelikon, Intersputnik has a long list of assets to tap, but only limited transponders to operate or lease. Intersputnik signed memorandums of understanding with INMARSAT and INTELSAT in 1983 and 1991, thus increasing its coverage area and its com-

petitiveness in the world market. Intersputnik not only markets services, but in the future will participate fully in the development and launching of the next generation of Russian communication satellites. The basic global services currently offered by Intersputnik are:-telephony, facsimile, telex and data exchange in international, domestic and regional public networks, as well as in dedicated networks;

-international exchange of TV and audio programs;

-regional TV and audio broadcasting in VSAT (very small aperture ter -minal) networks;
-establishment of videoconferencing networks;
-establishment of business communications networks, etc. (Upfront, 1993, p.28)

H. LOCSYST

Locsyst (Figure 7-4) has an unusual deployment technique. It deposits six satellites (a sextet) into 1500 kilometer circular orbit per launch. The

Figure 7-4. The Locsyst Spacecraft Deployment System (Johnson, 1991, p. 39)

system, if leased, would consist of 24 satellites (six satellites in each of four orbital planes). A military version of the Locsyst network was deployed between 1988 and 1990, after only two successful test launches in 1985. Development and deployment costs are estimated at 137 million rubles (1990 rubles) with an operational cost of approximately 18 million rubles. Initial launches for a commercial constellation could start as early as two years from signing the contract. The system promises "contact waiting time of 20 minutes or less and a data delivery time of less than two hours. SATELIFE, a humanitarian organization which supplies health-related information to underdeveloped countries, is studying the use of Locsyst primarily for simple data and FAX transmissions. Initial operational capability was scheduled for 1991. (Johnson, 1991, p. 39)

I. MARAFON

Professor Grigoriy M. Chernyavskiy, of the Russian Academy of Sciences, announced plans for a new Russian national space system at the American Institute of Aeronautics and Astronautics (AIAA) International Communication Satellite Systems Conference in 1992. This new system, name Marafon, was to "provide telecommunication links with maritime, airborne and ground-mobile user via relay satellites in the geostationary and

highly elliptical Earth orbits." (Chernyavskiy, 1992, p. 4) The Marafon system is supposed to target land-mobile users primarily, and fill the gap that the lack of cellular radiotelecommunications has left in the vast area of the CIS. The size of the system will be based on the forcasted number of potential users which was estimated by Professor Chernyavskiy as 300,000-350,00 units, and growing to 400,000 to 450,000 units by the year 2005. At that time the major developmental hurdle for the system was the widely varied operational frequencies (HF, C and L-band) of the Marafon system. (Chernyavskiy, 1992, p. 5)

J. MARATHON

This L-band mobile communications system is INMARSAT compatible, and operated under the cognizance of the Ministers of Communications and of General Machine Building. The Marathon was designed and built in response to the Gorizont's mobile communications limitations. The satellite communications services of the Marathon will provide telephone, telegraph and facsimile communications to mobile end-users (specifically ships, oil rigs, railway trains, etc.). (Commercial, 1993, p. 56) The system will utilize three to four Arcos satellites and two to four Mayak satellites (Figure 7-5), providing service to subscribers primarily in the northern latitudes (70°-90° North). Satellite-to-subscriber transmissions will be in the 1.5 Ghz frequency band for uplink and 1.6 Ghz for downlink. Arcos 's transponders are limited to 350

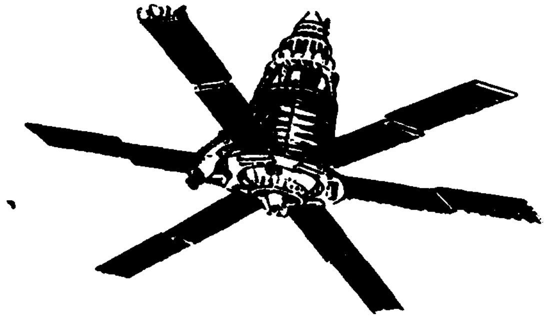

Figure 7-5. The Mayak Spacecraft (Johnson, 1991, p. 43)

duplex telephone channels, while Mayak is limited to 30 to 50 channels. (Commercial, 1993, p. 56) The two newest satellites in the Marathon system are to be launched in 1993-1994 and will include an improved Mayak spacecraft and improved Arcos spacecraft, each operating in L-band. The purpose of this launch is to make spare communications capacity commercially available to subscribers outside the CIS.(Commercial, 1993, p. 59)

K. NADEZHDA (HOPE)

The Nadezhda system (Figure 7-6) was deployed to bring the international search-and-rescue system, COSPAS-SARSAT, up to full complement. Nadezhda was a replacement for the aging Tsikada satellite. "Installed on board the satellite is equipment of a navigational system intended for de-

termining the locations of vessels of the merchant and fishing fleets of the Soviet Union, and also equipment for operation as part of the international spacecraft-aided system for locating and rescuing ships and airplanes in distress (COSPAS-SARSAT)."(Krasnaya, 1990, p. 1)

Transponders aboard the spacecraft are tuned to 121.5 MHz (Western VHF emergency and distress frequency) and 406 MHz. The equipment can only locate the VHF signal to within 15 kilometers. The Russians would prefer to see the 406 MHz frequency used worldwide, since transponders on

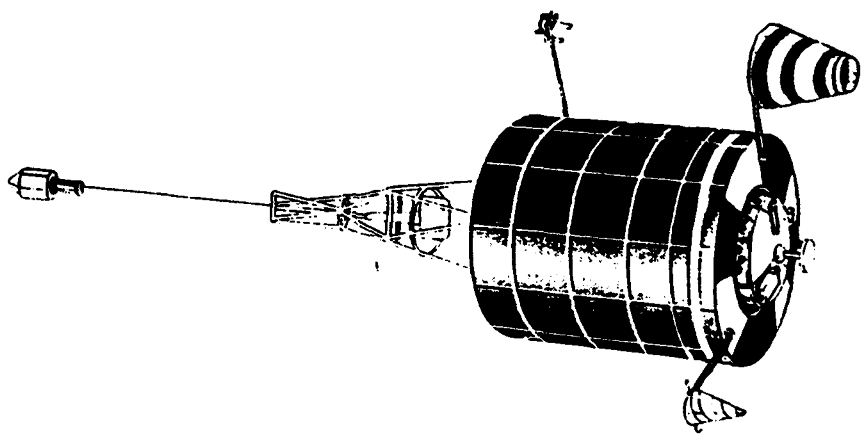

Figure 7-6. Nadezhda Spacecraft with COSPAS Transponder (Johnson, 1991, p. 54)

board the Nadezhda can provide beacon positions to within 2 kilometers and avoid atmospheric interference. Cospas control centers are located in Moscow, Vladivostok, Archangelsk, Novosibirsk, North and South America, as well as Europe and Australia. (JOHNSON, 1991,P. 55)

L. TSIKADA

Tsikada is a second generation Russian navigation satellite, which mimics the U.S. NAVSTAR GPS system. The Tsikada is primarily used by civilian organizations to locate Russian merchant and fishing vessels, geologists and oil workers via the shipborne Shkuna receiving-display equipment. The civilian system consists of four satellites whose orbital planes are separated by 45° of right ascension, in orbits identical to the military navigation satellites. In order to increase accuracy and timeliness of geolocation, the civilian satellites are placed in the opposite hemisphere of the military system which increases the accuracy and timeliness of data for users who can receive signals from both constellation. Differences between the civilian and military system are unknown. Tsikada satellites carrying the COSPAS-SARSAT fall under the Nadezhda.

M. ZERAKLO

Russia's Lavochkin Association has announced the design of a new communications satellite which can stand up against any Western satellite. Zeraklo, under the design of the Institute for Space Instrument Engineering, is said to have a power rating of 2960 watts, and carry ten wideband 9120 MHz transponders. (Satellites, 1993, p. 5) Antenna configuration will include "eight

fixed 1X1 spot beams, plus two mobile beams which can be shifted to any part of the total coverage area by mechanical movement of the antennas through the 17° in each axis." (Satellites, 1993, p. 5) According to Lavochkin representatives at the RUSSAT '93 conference, a 64 kilobytes per second transponder will cost $10,000 per year, as compared to a 8.448 megabits per second transponder at $1.27 million a year. The unit cost per satellite is put at approximately $66-70 million. Foreign investors are welcome.

VIII. THE TELEMEDICINE SPACEBRIDGE PROJECT

The previous chapters have provided insight and technical details of current and future Russian communication satellites and systems. How can these resources be used to further technical cooperation between the U.S. and Russia in response to manmade and natural disasters? The Telemedicine Spacebridge Project is a shining example of the mutual benefit from cooperation in space and on land.

The Telemedicine Spacebridge Project (TSP) is a demonstration of the capability of Telemedicine on a global scale. Telemedicine is "the use of telecommunications to aid the medical process through such things as consultation, telediagnosis, teleradiology and telepathology " using satellites and terrestrial fiber-optic telephone links.[(Zuzek, 1994, p. 1)]

This is not a new concept. In the 1970's medical consultations in remote regions of Alaska were assisted by NASA (National Aeronautics and Space Administration) satellites. Doctors, ministering to the earthquake victims in Soviet Armenia in 1989, received medical assistance, diagnosis, and consultation via a NASA-initiated Telemedicine Spacebridge. In addition, it has been a long term goal of NASA Life Sciences to standardize in-flight medical

procedures to facilitate mutual life sciences research with the Russians. The feasibility of the concept was demonstrated at the International Telemedicine Conference in 1991.

Using a Western Satellite Data Relay Network (WSDRN) satellite (Figure 8-1) and a prototype SDRN Russian ground station, a real time Telemedicine consultation was conducted between participants in Bethesda, Maryland, and a studio in Moscow (Figure 8-1). The SDRN ground station, located at the NASA Lewis Research Center in Cleveland, Ohio acted as the gateway (Figure 8-2).(Zuzek, 1994, p. 2) Being the gateway, NASA Lewis was the connection between the GTE Spacenet Gstar II satellite (located at 125° West longitude and the Russian WSDRN satellite (16° West longitude). Relay from the ground site in Cleveland was via fiber-optic land line. The demonstration project at NASA Lewis was successfully completed in May 1994.

Why were two satellites needed if the WSDRN was visible from the U.S. East Coast? U.S. domestic satellites have nearly identical uplink and downlink coverage areas, so it is possible to receive your own downlink. Not so with the Russian WSDRN satellite. For all intents and purposes, the SDRN is comprised of two separate transponders and steerable antennas, one for uplink and one for downlink. Essentially, "the Cleveland SDRN earth station can send signals to Moscow "Central " earth station, but the Cleveland SDRN

station cannot receives its own downlink." (Zuzek, 1994, p. 3) The hop from Moscow to Cleveland is accomplished via the WSDRN, and the hop from Cleveland to participating U.S. medical centers is provided by the GTE Spacenet-II domestic Ku-band satellite.

Telemedicine uplink and downlink services are provided at the Uniformed Services University of the Health Sciences (USUHS) in Bethesda, Maryland, LDS Hospital, Salt Lake City, Utah, University of Texas, Health Science Center, Houston, and Fairfax Hospital, in Fairfax, Virginia. Only one site at a time is designated a primary site, and can uplink live video. Secondary sites can receive video and receive and transmit audio during the conference. Video is full color and real time.

This is not a perfect system. According to Jim Hollansworth at NASA Lewis, there have been occasions where "some General in Russia wanted to use the WSDRN, flipped a switch, and we lost the link in mid-conference." (Hollansworth, 1994) Still, the joint Russian/U.S. project has been successful. This experience could revolutionize the way medical services are provided in remote regions of the world and the delivery of humanitarian aid after a natural or man-made disaster. In addition, the knowledge gained in life sciences by both participants could have a long term effect on capabilities and knowledge for all future space operations.

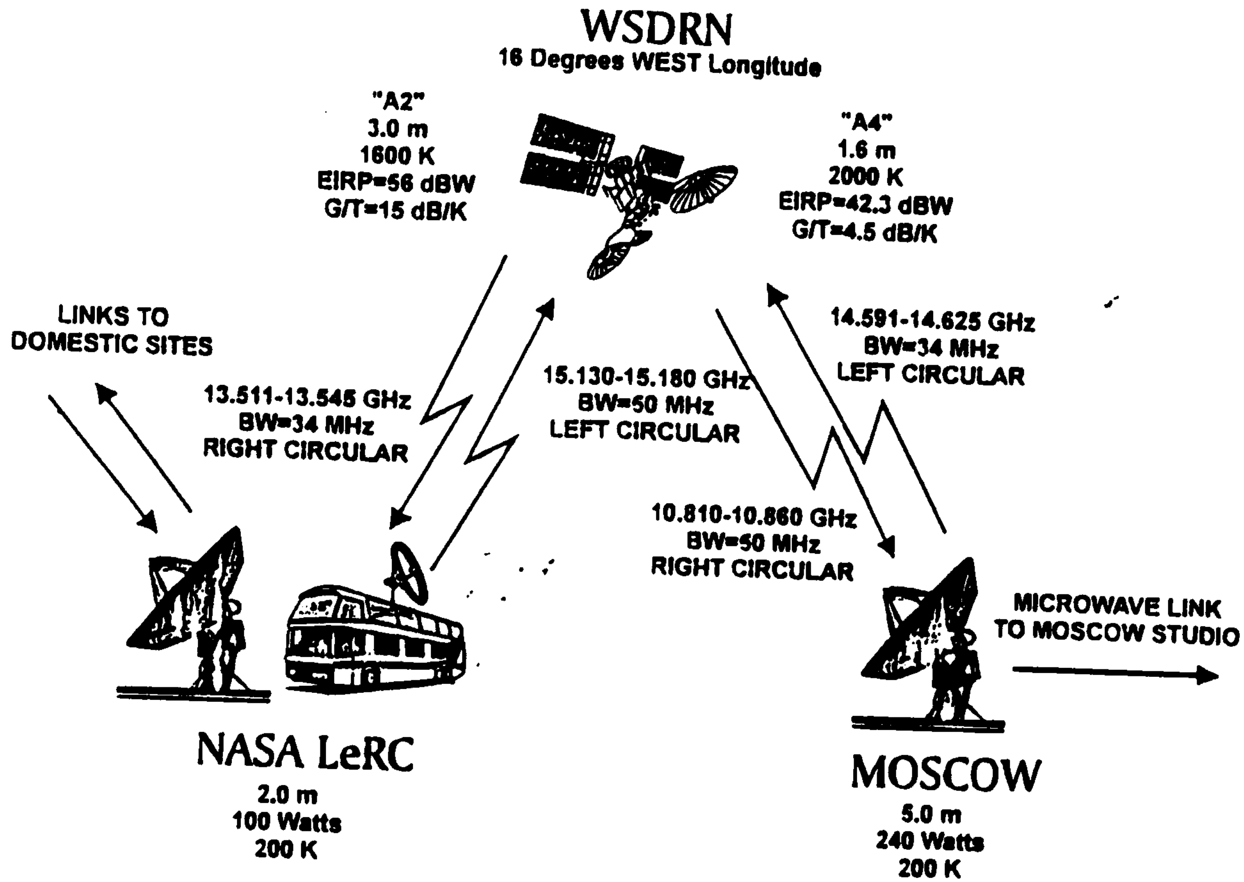

Figure 8-1. WSDRN Link Budget Schematic
(Zuzek, 1994)

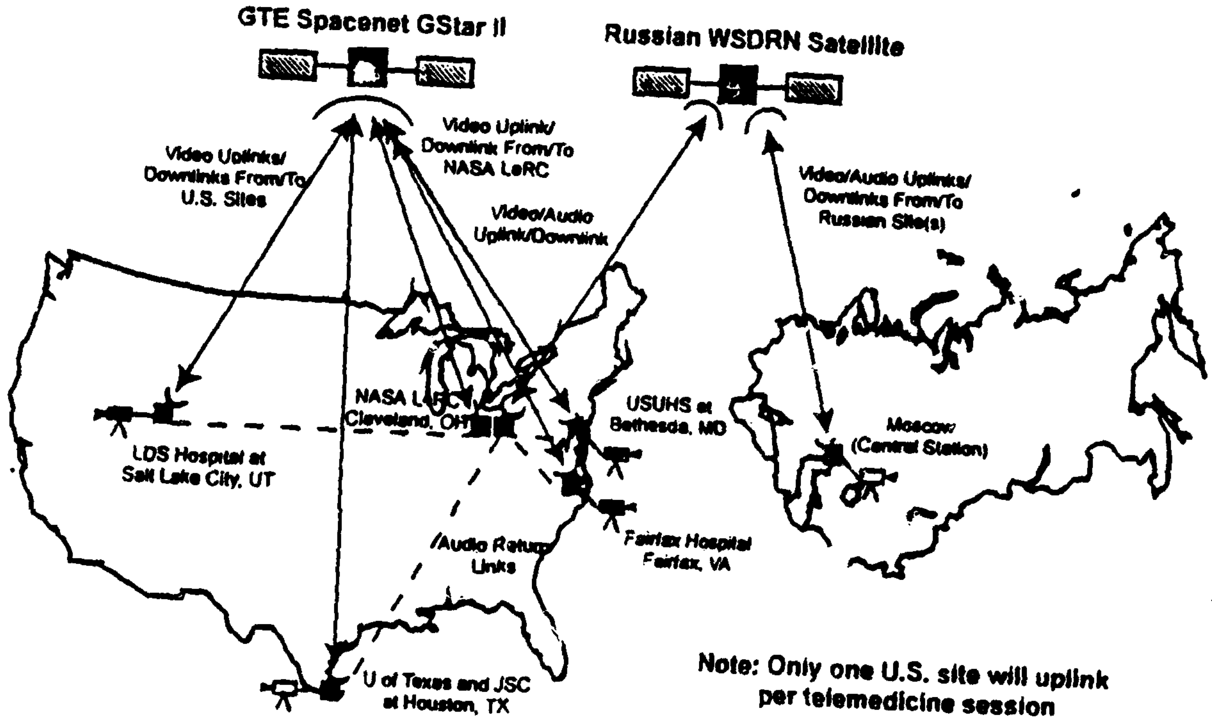

Figure 8.2 Telemedicine Spacebridge System Overview (Zuzek, 1994)

IX. SUMMARY AND CONCLUSIONS

Although the major systems were discussed in detail, discussion of the miscellaneous systems only touched the tip of the iceberg. The major systems appear to be aging and ailing designs, which serve as the basis for many of the "on-order" and future (miscellaneous) systems. It will be hard for any emerging satellite industry to make its way in the world commercial satellite market by simply adding new frills to an old bus, such as the Gorizont. While it is true that the Gorizont bus has proved reliable for station keeping and support of add-on transponders, it is also true that Russian transponders have proven to be only occasionally reliable.

The usability and reliability of the current constellations which make up the Russian satellite communication network would prove very valuable in a time of man-made or natural disaster if there was complete interoperability with international commercial satellites and ground control stations. This is obviously not the case. The Russian offers to provide ground control service for leased satellites are not bargains, but an admission that their technology lags behind the rest of the world.

A case in point is the Telemedicine Spacebridge Project. The engineers at NASA Lewis used off-the-shelf equipment to establish links with U.S. domestic satellites. However, the Russian space segment required the construction of a mobile "Russian-built" ground station in order to coordinate and communicate with the WSDRN satellite. Jim Hollansworth said the Russian engineers intimated that the equipment in the ground station was their "state of the art" military equipment.(Hollansworth, 1994) The equipment required no less than 30 minutes to warm up, and had serious problems with internally generated noise, seriously effecting the quality of received video.

Fulfilling the MOU appears to be a one-sided proposition, with the Russian Federation benefiting from U.S. commercial satellite technology. With this information in hand, they will no doubt set about to reverse engineer to make their own commercial satellite industry more competitive in what is a vicious, burgeoning marketplace in space.

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